# Variation and Pearson correlation coefficients of Warner-Bratzler shear force measurements within broiler breast fillets[1]

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**ABSTRACT** Measurements of texture properties related to tenderness at different locations within deboned broiler breast fillets have been used to validate techniques for texture analysis and establish correlations between different texture evaluation methods. However, it has been demonstrated that meat texture can vary from location to location within individual muscles. The objective of our study was to investigate the intramuscular variation and Pearson correlation coefficients of Warner-Bratzler (WB) shear force measurements within early deboned broiler breast fillets and the effect of deboning time and cold storage on the variation and correlation coefficients. Broiler breast fillets were removed from carcasses early postmortem (2 h) and later postmortem (24 h). Storage treatments of the 2 h samples included 0 d, 7 d at 3°C, 7 d at −20°C, and 6 d at −20°C plus 1 d at 3°C. The WB shears of cooked fillets were measured using a TA-XTPlus Texture Analyzer and a TA-7 WB shear type blade. Our results showed that although the average WB shear force values differed within the 0-d, 2-h fillets, compared with the variation among the fillets within the treatment, the difference within a fillet is still evidently small. The Pearson correlation coefficients were significant between the locations; however, values of the correlation coefficients depended on the paired locations. Location differences in the WB shear values and the correlation coefficient values between them changed with deboning time and cold storage. These results demonstrate that the variation of WB shear force measurements is substantial within early deboned broiler breast fillets and the Pearson correlation coefficient values of the measurements vary among the locations. Both the variation and the Pearson correlation coefficients can be affected by postmortem aging time and storage. The differences in the means between the locations in early deboned breasts are much smaller than the variation among the fillets.

**Key words:** texture, broiler breast, deboning time, storage, Warner-Bratzler shear

## INTRODUCTION

Tenderness or texture is a major quality concern with boneless skinless broiler breast fillets (Sams, 1999). Tenderness is commonly correlated with instrumental or sensory methods, or both, with measurements on a small portion or a strip of fillet. Lyon and Lyon (1991) used 1.9-cm-wide strips removed from the fillets deboned at various postmortem times for the Warner-Bratzler (**WB**) shear, Allo-Kramer (**AK**) shear, and sensory tests. Sams et al. (1990) used $3.5 \times 2.0 \times 0.7$-cm strips for AK shear and $5.0 \times 1.0 \times 0.7$-cm strips for WB shear of the early harvested fillets. Xiong et al.

(2006) used 1.27-cm cubes for consumer testing of fillet texture. Smith et al. (1988) used sample size $2- \times 2$-cm for AK shear and texture profile analysis (**TPA**) of hot-boned and chill-boned broiler breast meat. Because only a very small portion of meat is needed for texture evaluation, a couple of studies have attempted to use the meat from different locations within the same chicken breast fillet to validate the different techniques for texture analysis and establish a correlation between the tested techniques. For study on the relationship between texture instrumental measurements and sensory texture evaluation, Lyon and Lyon (1990, 1991) removed two 1.9-cm-wide strips from fillets that were deboned at 0, 2, 6, and 24 h postmortem, using one strip for sensory evaluation and the other for WB and AK shear evaluation. In another attempt, Lyon and Lyon (1996) sectioned the intact breast into three 1.9-cm strips (strips B, C, and D shown in Figure 1) from each fillet deboned at 2, 6, and 24 h postmortem; one (strip B) was used for instrumental texture analysis (WB and

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AK) and the other 2 were used for sensory evaluation. Xiong et al. (2006) used a sectioning method similar to Lyon and Lyon in their 1996 study and divided fillets deboned at various postmortem times (from 0.25 to 24.0 h) into 3 strips (1.9 or 2.0 cm each) to compare different instrumental methods for predicting sensory tenderness of broiler breast meat. However, it has been repeatedly reported that tenderness or shear force values of meat can vary substantially from location to location within the boundaries of individual muscles. Reuter et al. (2002) concluded that the tenderest region of beef biceps femoris was toward the sirloin end and the toughest region was in the middle based on the analysis of WB shears. There was a 2-fold difference in shear values within the muscle. Sigurgisladottir et al. (1999) reported that in salmon fillets, the least shear force was in the center and became a little greater toward the head and much greater toward the tail. There was a 3-fold change in shear values within a salmon from head to tail. Alsmeyer et al. (1965) found that the lateral locations of pork longissimus dorsi were most tender, and the medial locations the least tender. Intramuscular variation has also been reported within deboned chicken breast fillets. In their texture analytical methodology study, Smith et al. (1988) sampled 2- × 2-cm chunks from 3 locations of hot-boned and 24-h deboned fillets, anterior (strip A area in Figure 1), middle (strip C area in Figure 1), and posterior (around strip D area in Figure 1), and found that there were significant differences in the AK shear and TPA parameters of hardness, springiness, cohesiveness, and chewiness between the locations. The highest AK shear value was in the anterior location for hot-boned fillets (1.5 times greater than the posterior location) and in the posterior location for 24-h deboned fillets (1.4 times greater than the anterior location). Papa and Lyon (1989) divided hot-boned and 24-h deboned breast fillets into 5 locations and measured the texture using both TPA and WB shearing methods. They demonstrated that there was a significant difference in WB shear of cooked hot-boned fillets (a 1.75-fold difference), but there was no difference in 24-h deboned fillets between the cranial and caudal location. These results suggest that there might be significant differences between the locations used in previous researches and that the differences could be affected by postmortem deboning times.

Warner-Bratzler shear force measurements are the most popular indicator for meat texture (Culioli, 1995). The WB has been widely used to predict tenderness or texture quality of poultry breast fillets (Lyon and Lyon, 2001). The objective of this study was to investigate the variation and Pearson correlations (linear relationships) of WB shear force measurements from different locations (strips B, C, and D in Figure 1) within early deboned broiler breast fillets (pectoralis major). We also studied the effect of deboning time and cold storage on the variation and correlations. The results from this study can further demonstrate texture or tenderness variations and their relationships between the different locations within broiler breast fillets, and compare the variation within a fillet to the variation among the fillets. The results should also be useful for poultry researchers and quality assurance personnel to better understand published texture analysis results, plan experimental designs, and determine sampling methods for chicken fillet texture measurements.
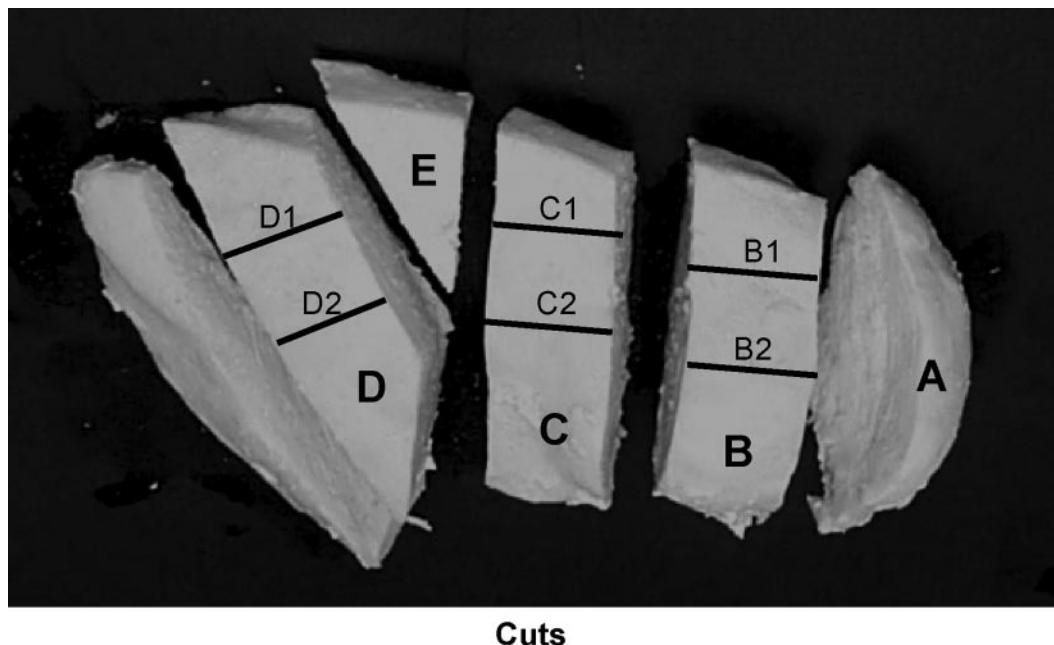


**Cuts**

**Figure 1.** Diagram of scheme for sectioning the cooked broiler breast fillet to obtain test portions or 1.9-cm strips for Warner-Bratzler shear measurements.

**Table 1.** Raw material characteristics of chicken fillets deboned at 2 h postmortem

| Item | Carcass weight (g) | L* | a* | b* | pH |
|------|-------------------|------|----------------|-------------|------------|
| Mean | 1,525 | 55.7 | 0.5 | 12.6 | 6.0 |
| SD | 131 | 2.9 | 0.7 | 2.0 | 0.2 |
| Range | 1,298 to 1,820 | 47.3 to 61.5 | −1.0 to 3.6 | 6.4 to 18.3 | 5.7 to 6.4 |

## MATERIALS AND METHODS

### Experimental Treatments

Five treatments were included in this study. They were 2 h (2-h deboned chicken breast with no storage), 24 h (24-h deboned chicken breast with no storage), 7 dR (2 h deboned and stored 7 d in a 3°C refrigerator), 7 dF (2 h deboned and stored 7 d in a −20°C freezer), and 6 dF +1 dR (2 h deboned and stored 6 d in a −20°C freezer before removed to the 3°C refrigerator for 1 d). For treatment 7 dF, samples were cooked from the frozen stage. One of the reasons to investigate the effect of the cold storage and deboning time on the variation and Pearson correlation coefficients of WB shear force measurements within chicken breast fillets is that the chicken breast muscles used for texture studies are very often deboned at various postmortem time and stored at a refrigerated or frozen temperature before cooking. McKee et al. (1997) froze fillets deboned at 1 and 24 h postmortem at − 20°C and cooked them from a frozen stage in the study on the effect of aging after prerigor deboning on broiler breast tenderization. Lyon et al. (2001) stored breast samples deboned 8 h postmortem at −18°C and thawed overnight at 4°C before cooking for WB shear measurements.

### Chicken Samples

Broiler carcasses (about 6 wk old) were obtained from a local processing plant immediately after the flow-through, paddle-type chiller (prechill plus chill time averaged 60 to 65 min). The carcasses were placed in a cooler and transported to the laboratory within 20 min. Carcass temperatures were 3 to 4°C on arrival. Breast muscles for the 2-h group were removed from carcasses within 15 to 25 min of arrival at the laboratory (Liu et al., 2004). One fillet from each carcass was used for treatment 2 h (no storage). The other halves were vacuum-bagged in individual polymeric bags (Seal-a-Meal, The Holmes Group, El Paso, TX) and stored 7 d in a refrigerator (treatment 7 dR), a freezer (treatment 7 dF) or a freezer and thawed in a refrigerator (treatment 6 dF + 1 dR). For treatment 24 h, the other breast half was left on the carcass with normal attachment to the skeletal restraints (intact). The carcass with the fillet was then placed in a Ziploc freezer bag (Ziploc Brand Freezer Bags, Johnson & Son Inc., Racine, WI) and stored 22 h at 1 to 2°C (treatment 24 h) before deboning. Carcass weight, fillet pH, and color of the 2-h birds are shown in Table 1. The range of b* values in this study was much larger than those reported by most authors using the same CIE L*a*b* scale. However, our result is consistent with the recent discovery by Galobart and Moran (2004). In their study, 500 broilers were used and chicken breast fillets were sorted into 3 categories, pale, dark, and normal based on L* value. They found that the range of b* value of dark fillets was from 8.5 to 19.6, and for pale fillets, the range was from 8.5 to 25.2.

### Color, pH, and Warner-Bratzler Shear Measurements

Color and pH measurements (Table 1) were performed on chicken breast fillets after deboning. Surface color measurements (L*, a*, and b* values) were carried out with a Minolta spectrophotometer CM-2600d (Konica Minolta, Ramsey, NJ) with settings of illuminant C, 10° observer, specular component excluded, and an 8-mm aperture. Surface areas were selected that were free from obvious defects (bruises, discolorations, hemorrhages, or any other conditions that might have prevented uniform color readings). Three measurements were taken on the bone side of the fillet. Each measurement was the result of 3 averaged readings by the spectrophotometer. The pH of the fillets was determined with a Sentron Model 2001 pH meter (Sentron Gig Harbor, WA) and a piercing probe (Lance FET Tip) at the cranial end (wing end). Between measurements, the probe tip was cleaned with a toothbrush and rinsed with deionized water.

For WB shear force measurements, the vacuum-bagged samples were cooked in a Henny Penny MCS-6 combination oven (Henny Penny Corporation, Eaton, OH) at 85°C (185°F) with the tender steam setting to reach an internal temperature of 78°C. The internal temperatures were checked in the thickest part of each fillet with a hand-held digital thermometer fitted with a hypodermic needle probe (Doric Digital Thermometer, Model 450-ET, Doric Scientific, San Diego, CA). After reaching ambient temperature, three 1.9-cm-wide strips were removed from the breast by cutting next to a template aligned parallel to the muscle fibers and adjacent to the cranial end (see Figure 1). Each strip was sheared in 2 locations (locations 1 and 2), and heights at each shear point were recorded so that values could be expressed as force/1.9 cm height. Maximum force measured to shear the strips was expressed as Newtons.

### Statistics

The experiments were conducted in a paired comparison design. Each of cold storage treatments (includ-

ing 7 dF, 7 dR, and 6 dF + 1 dR) and treatment 24 h were paired to only treatment 2 h. No paired comparison was conducted between the cold storage treatments and between 24-h samples and any of the cold storage treatments. Treatment 2 h was replicated 5 times (total 50 individual fillets). For the storage and deboning effect, the tests were replicated 2 times with total 7 to 10 individual fillets (see Table 2). For statistical analyses, the measurements of WB shear force of each treatment were analyzed by descriptive statistics (Microsoft Excel, Microsoft Corporation, Redmond, WA) for means, SD, and ranges. The differences between strips within samples were tested by the paired comparison analysis. In the statistical model, the WB shear measurements (such as B1 and B2) of each strip (such as B) from all replications of each treatment were combined and paired with those from corresponding strip (such as 1 and 2 of C or D) from the same fillet to test strip effect within fillets. The same model was used to calculate the Pearson correlation coefficients within samples (paired samples correlations). When the correlation coefficients were calculated between treatments, only 2-h deboned fillets from the same birds as those for the storage or 24-h treatment were used. For example, for the paired correlation of 2-h samples with 24-h samples, only 10 fillets were used from the total of fifty 2-h fillets, and these 10 fillets were from the same birds but the different side as the 24-h samples. The same cut position from the same strip of the fillets from the same birds and different treatments were paired. For example, WB shear value of cut position B1 of strip B of a 2-h fillet was lined up to the WB shear value of cut position B1 of a 24-h fillet from the same bird (different side); B2 of the 2 h sample lined up with B2 of the 24-h sample, and so on. The comparisons of mean differences and the calculation of Pearson correlation coefficients were made with SPSS 9.0 software package (SPSS Inc., 1999). The null hypothesis implied no difference in the measurement means and that Pearson's r-value equals 0 in correlation analysis ($P = 0.05$).

## RESULTS AND DISCUSSION

### Warner-Bratzler Shear Variation and Pearson Correlation Coefficients Within 2-h Deboned Broiler Breast Fillets

The overall average WB shear values with SD and range of the 2-h fillets are shown in the first row of Table 2. These results are consistent with several previous reports on WB shear values of 2-h deboned fillets. Lyon and Lyon (1996) reported that the average WB shear value for intact broiler breasts deboned at 2 h postmortem was 9.53 kg of force (**kgf**, 93 N) for left breast and 10.12 kgf (99 N) for right breast (vs. 107 N in our study) with SD 3.89 (38) and 4.49 kgf (44 N; vs. 46 N in our study), respectively, ranging from <3.62 kgf (36 N) to >12.60 kgf (124 N; vs. 24 to 246 N in

our study; Lyon and Lyon, 1991). Xiong et al. (2006) found that in 2-h deboned breast samples used for sensory tenderness intensity analysis, 8.1% was identified as extremely tough by consumer panel (corresponding to >16.83 kgf or 165 N), and 4.1% as extremely tender (corresponding to <1.82 kgf or 18 N). Our result further demonstrates that the variation in WB shear force of 2-h fillets was considerable.

The average WB shear force values and SD for different locations within 2-h fillets are shown in Table 3. The values were in the following order: strip C (117 N) > strip D (107 N) > strip B (96 N). The SD of the WB shear measurements were similar to one another (48, 47, and 41 N, respectively) and did not substantially differ from the overall SD (46 N, Table 2). The paired samples t-test shows that there were differences in the average WB shear values between strip B and strip C and between strip B and strip D. No difference was noted between strip C and strip D at the 0.05 level. Significant differences in average TPA values and shear force measurements between intramuscular locations of chicken fillets have been demonstrated by previous researchers. Papa and Lyon (1989) reported that for hot-boned broiler fillets, average hardness values (kgf) measured by TPA at the cranial muscle location were significantly greater than the middle and caudal locations. The average WB shear values of the hot-boned fillets toward the cranial area were greater than those toward the caudal area. Smith et al. (1988) found that the AK shear value at the posterior location was significantly greater than the middle and anterior locations for 24-h deboned samples. Our results further demonstrated that texture or tenderness differences existed within the 2-h fillets. The differences found in our test could result from differences in rigor onset within individual broiler breast muscles. Papa and Fletcher (1988) demonstrated that the anterior location of hot boned fillets reached the onset phase of rigor in about 1 h, whereas those at the posterior location required between 2 and 4 h postmortem. In addition, our result showed that the differences ($\leq 21$ N) in the means (ranged from 96 to 117 N) between the locations in early deboned breasts were much smaller than the variation (>220 N) among the fillets (ranged from 24 to 246 N). The mean value obtained from any of the 3 locations tested in our study can be used to indicate the texture properties of the particular fillet samples.

The first row of Table 4 shows the Pearson correlation coefficients or the linear relationship between the strips of treatment 2 h. The low P-values ($P < 0.01$) of the strip pairs suggested that Pearson's correlation coefficient was different from zero or there was evidence of an association (or a significant relationship) in texture measurements between any 2 of the strips measured in our experiment. However, the values of correlation coefficients differed with the strip pairs. The r-value between the strip pair B and C was 0.81, meaning that 66% (equal to $0.81^2$) of variance in the WB shear values of strip C can be explained by the WB shear values

**Table 2.** Overall mean, SD, and range of Warner-Bratzler shear values of chicken breast fillets

| Treatment[1] | Sample size (n) | Mean of shear value (N) | SD | Range |
|---|---|---|---|---|
| 2 h | 50 | 107 | 46 | 24 to 246 |
| 24 h | 10 | 37 | 12 | 10 to 66 |
| 7 dR | 8 | 82 | 35 | 36 to 176 |
| 7 dF | 7 | 79 | 36 | 28 to 236 |
| 6 dF + 1 dR | 10 | 51 | 31 | 12 to 177 |

[1]Treatments: 2 h = 2-h deboned chicken breast with no storage; 24 h = 24-h deboned chicken breast with no storage; 7 dR = 2 h deboned and stored 7 d in a 3°C refrigerator; 7 dF = 2 h deboned and stored 7 d in a −20°C freezer; and 6 dF +1 dR = 2 h deboned and stored 6 d in a −20°C freezer before removed to the 3°C refrigerator for 1 d.

of strip B and vice versa. This suggests that strip B and strip C are strongly correlated and each strip can indicate the texture of the other strip. However, the linear correlation of the other 2 strip pairs was weak. The r-value between strip B and strip D was 0.36 (corresponding only 13% of variance), and the r-value between strip C and strip D was 0.54 (corresponding to only 29% of variance), indicating that there was no strong Pearson association in the WB shear measurements between these strips and that the measurement of WB shear in one strip was not a good indication for the texture property of the other. Szczesniak and Torgeson (1965) summarized 38 studies on Pearson correlation coefficients between the WB shear and sensory measurement of meat texture and found very wide correlation coefficients (ranging from r = −0.001 to r = −0.942). Three types of error were thought to cause the variation, including instrument error, sensory panel problems, and commodity uniformity. The current research showed that the Pearson coefficients varied largely even with the same instrument of texture analysis within the same chicken muscle and demonstrates the difficulty of establishing successful Pearson correlations of texture measurements between 2 different destructive texture analytical techniques, which has been a challenge for many scientists for many years.

### Effect of Deboning Time and Cold Storage on Warner-Bratzler Shear Variation and Pearson Correlation Coefficients Within Broiler Breast Fillets

Our study also demonstrated that the WB shear values, the variation of WB shears within individual fillets and the Pearson correlation coefficients of the WB shear measurements were substantially affected by deboning time (aging) and cold storage (Tables 2, 3, and 4). For example, for the 24-h samples the overall average WB shear value was 37 N with the SD of 12 compared with 107 N and 46 of the 2-h sample (Table 2), respectively. There were no differences in the average WB shear values between the strips (Table 3). There was the relationship ($P < 0.05$) between the strip pair B and C and between the strip pair C and D (Table 4), but the association of the measurements was not strong ($r^2 \leq$ 0.26 or 26%). There was no proof of linear relationship

in the WB shear values between strip B and strip D ($P$ = 0.15; r = 0.35).

Cold storage also resulted in reduced average values of the WB shears (Tables 2 and 3), especially treatment 6 dF + 1 dF (average WB shear was 51 N with the SD of 31), which resulted in reduced WB shears by more than 50% in our test. The effect on variation of WB shears within chicken fillets differed with the cold storage conditions. Within the 7 dR fillets (Table 3), the mean WB shear value of strip C was greater than that of strip B. However, there were no differences in the WB shears between the strip pair B and D or the strip pair C and D. For treatment 7 dF (Table 3), the average WB shear value of strip D was greater than that of strip B; however, there were no differences between strip B and strip C and between strip D and strip C. For treatment 6 dF + 1 dR (Table 3), there was no difference between the strip pairs. Regardless of the storage conditions, there was a Pearson correlation between the strips (Table 4) within samples ($P < 0.01$), and that was relatively strong (r ≥ 0.75), suggesting that the WB shear measurements on one strip area can be used to indicate the values or the tenderness on the other strip areas for any of the 7-d, cold-stored samples. The inconsistency in the correlations for 24-h samples could be due to random variation and needs to be confirmed by a larger sample size.

It has been reported that postmortem aging resulted in shear force changes within broiler breast fillets and

**Table 3.** Average Warner-Bratzler shear values (N) and SD (mean ± SD) of strips B, C, and D of the cooked broiler fillets

| Treatment[1] | Warner-Bratzler shear force (N) | | |
|---|---|---|---|
| | Strip B | Strip C | Strip D |
| 2 h | 96 ± 41[b] | 117 ± 48[a] | 107 ± 47[b] |
| 24 h | 37 ± 12[a] | 36 ± 10[a] | 38 ± 15[a] |
| 7 dR | 76 ± 34[b] | 89 ± 35[a] | 83 ± 36[ab] |
| 7 dF | 71 ± 25[b] | 76 ± 28[ab] | 92 ± 50[a] |
| 6 dF + 1 dR | 52 ± 29[a] | 53 ± 38[a] | 48 ± 25[a] |

[a,b]Mean values with no common superscript in the same row are significantly different from each other ($P < 0.05$).

[1]Treatments: 2 h = 2-h deboned chicken breast with no storage; 24 h = 24-h deboned chicken breast with no storage; 7 dR = 2 h deboned and stored 7 d in a 3°C refrigerator; 7 dF = 2 h deboned and stored 7 d in a −20°C freezer; and 6 dF +1 dR = 2 h deboned and stored 6 d in a −20°C freezer before removed to the 3°C refrigerator for 1 d.

**Table 4.** Pearson correlation coefficients and correlation significance of Warner-Bratzler shear values between strips B, C, and D

| Treatment[1] | Pair strip B – strip C | | Pair strip B – strip D | | Pair strip C – strip D | |
|---|---|---|---|---|---|---|
| | r-value | Significance | r-value | Significance | r-value | Significance |
| 2 h | 0.81 | <0.01 | 0.36 | <0.01 | 0.54 | <0.01 |
| 24 h | 0.47 | 0.04 | 0.35 | 0.15 | 0.51 | 0.03 |
| 7 dR | 0.83 | <0.01 | 0.77 | <0.01 | 0.77 | <0.01 |
| 7 dF | 0.80 | <0.01 | 0.75 | <0.01 | 0.80 | <0.01 |
| 6 dF + 1 dR | 0.83 | <0.01 | 0.78 | <0.01 | 0.92 | <0.01 |

[1]Treatments: 2 h = 2-h deboned chicken breast with no storage; 24 h = 24-h deboned chicken breast with no storage; 7 dR = 2 h deboned and stored 7 d in a 3°C refrigerator; 7 dF = 2 h deboned and stored 7 d in a −20°C freezer; and 6 dF +1 dR = 2 h deboned and stored 6 d in a −20°C freezer before removed to the 3°C refrigerator for 1 d.

that refrigerated and frozen storage could cause physical and biochemical changes in deboned broiler fillets. Smith et al. (1988) found that in hot-boned fillets, AK shear values of the anterior area were significantly greater than those of the posterior area; however, in 24-h deboned fillets, AK shear values of the posterior area were significantly greater than those of the anterior area. Papa and Lyon (1989) reported that the WB shear values of the muscle location close to the cranial area were significantly greater than those of the muscle location close to the caudal area in hot-bone fillets; however, after 24 h of aging, there was no difference in WB shears between these 2 locations. McKee et al. (1997) discovered that storage of 1-h deboned fillets for 71 h at <2°C reduced AK shear values and increased myofibrillar fragmentation. Lyon et al. (2001) conducted a study of the effects of storage temperature and duration on sensory quality, WB shear values, and near-infrared spectroscopy of broiler breast fillets deboned at 8 h postmortem. The authors reported that after 2 d of storage, the WB shear values of the fillets stored at −3°C were significantly greater than those at 4°C. By storage d 7, the sensory attributes of moisture release, rate of breakdown, and bolus wetness of the fillets stored at 4°C scored greater than those at −12°C. Chemometric analysis of near infrared spectroscopy discriminated between the unfrozen and frozen samples over storage, indicating that there were differences in myoglobin and oxidative states between the 2 samples. Our results further demonstrate that postmortem deboning time and cold storage can not only affect the WB shear values or tenderness and the variation in the WB shear values or tenderness within broiler fillets, but may also result in changes in linear correlations between the texture measurements.

## Correlation Coefficients of Warner-Bratzler Shear Values Between Treatments

Table 5 shows the Pearson correlations of the WB shear values of treatment 2-h samples paired with those of the other treatment samples. There were correlations in the WB shear measurements between treatment 2 h and any one of the other treatments ($P \leq 0.02$). How-

ever, the correlation coefficients are fairly small. The strongest correlation was found between treatment 2 h and treatment 7 dF (r = 0.71), followed by the correlation between treatment 2 h and treatment 6 dF + 1 dR (r = 0.53). The weakest correlation was noticed between treatment 2 h and treatment 24 h. These results suggest that WB shear values obtained from 2-h fillets that are frozen stored and cooked from frozen stage correspond relatively better to the texture measurement or properties of fillets without storage. In other words, if you have to store deboned fillets for texture analysis before cooking, the fillets should be stored in a freezer and cooked directly from the frozen stage.

The weak correlation (r ≤ 0.71) in WB shear force measurements between 2 h-deboned samples and the stored samples or 24-h samples could be explained by differences in biochemical mechanisms for postmortem rigor and tenderization of chicken breast meat during aging. The toughness of early deboned chicken breast fillets is believed to result from change in muscle tension or postmortem sarcomere shortening. However, the degradation of muscle ultrastructure, specifically the rupture of the actin-Z-disc connection has been hypothesized to be responsible for resolution of rigor or tenderization of early deboned chicken breast meat (Lyon and Buhr, 1999). Herring et al. (1965) reported that sarcomere length prerigor and during rigor was positively correlated with tenderness, whereas fiber diameter was negatively correlated with tenderness. Yu et al. (2005) found that the myofibrillar fragmentation index of pre-

**Table 5.** Pearson correlation coefficients and correlation significance of Warner-Bratzler shear values between treatment 2 h (2 h deboned and no storage) and the other treatments[1]

| Correlation pair | r-value | Significance |
|---|---|---|
| 2 h vs. 24 h | 0.29 | 0.02 |
| 2 h vs. 7 dR | 0.43 | <0.01 |
| 2 h vs. 7 dF | 0.71 | <0.01 |
| 2 h vs. 6 dF + 1 dR | 0.53 | <0.01 |

[1]Treatments: 24 h = 24-h deboned chicken breast with no storage; 7 dR = 2 h deboned and stored 7 d in a 3°C refrigerator; 7 dF = 2 h deboned and stored 7 d in a −20°C freezer; and 6 dF +1 dR = 2 h deboned and stored 6 d in a −20°C freezer before removed to the 3°C refrigerator for 1 d.

rigor chicken breast muscle that was stored in a freezer for 48 h and thawed at 18°C was significantly less than those thawed at 0°C or those stored at refrigerated temperature (2°C). The myofibrillar fragmentation index of the 0°C thawed and 2°C chilled fillets was also significantly greater than the prerigor control (no storage). There was negative correlation between myofibrillar fragmentation index and the shear force measurements. Xiong et al. (2006) and Lyon and Lyon (2001) reported that the delay of deboning time resulted in not only reduced shear force values and also changed distribution of tenderness or shear force among chicken breast fillets. Our results in this study further demonstrate that the effect of deboning time and storage method on the WB shear of early deboned chicken breast meat is independent of the original texture status.

## CONCLUSIONS

Within the middle area of early deboned (2 h) broiler breast fillets, the average WB shear force measurements significantly differed, further demonstrating that there is variation in texture properties or tenderness within the deboned chicken fillets. Although the WB shear values between the sampled locations within individual fillets were linearly correlated (Pearson correlation), the strength of the correlation varied, suggesting that we should be cautious when we use the measurement from one location to indicate texture of the entire breast. Postmortem aging affected the variation and correlation coefficients of the WB shear values. Compared with 2-h deboned fillets, 24-h deboning resulted in reduced variation of WB shear values within fillets and changed the linear relationship of the WB shears between the sampled locations. Cold storage also changed the variation and correlation coefficients. The effects on the intramuscular variation of texture differed with storage conditions. Cold storage for 7 d resulted in increased value of the Pearson correlation coefficients between the tested locations.

## ACKNOWLEDGMENTS

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